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NEW MECHANICAL POWER.

THE APPLICATION

OF

ELECTRO-MAGNETISM

AS A MOTIVE POWER TO MACHINERY;

CONTAINING

A SYNOPSIS OF THE MOST IMPORTANT FACTS AND DISCOVERIES

IN

ELECTRICITY, MAGNETISM AND ELECTRO-MAGNETISM;

WITH A SKETCH OF

RECENT INVENTIONS AND OPINIONS OF SCIENTIFIC MEN.

NEW-YORK:
SOLD BY WILEY & PUTNAM, 161 BROADWAY; & W. H. WILLIAMS, 9 JOHN-ST.
1839.

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District of New York

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PREFACE.

THE practicability of applying the newly discovered power of Electro-Magnetism to the movement of machinery, is a discovery which may be said to open a new era in science and the arts. The following pages have been prepared for the information of inquirers who have not time nor opportunity for research in scientific journals and other works where an account of recent discoveries are recorded.

Before describing the Magnetic Engine exhibited at the Twelfth Annual Fair of the American Institute, we deem it proper to give a brief sketch of the rise and progress of the Science of Electro-Magnetism, with reference to its application as a motive power to machinery, together with such general facts as may be necessary to enable those not familiar with the subject, to understand the most important phenomena of Magnetism and Electricity, and the connection which is now ascertained to exist between these two sciences.

The facts here stated are compiled from the latest and best authorities, and this sketch, therefore, may be found useful for future reference.

NEW-YORK, October, 1839.

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ORDINARY MAGNETISM.

It was known to the ancients that an ore of iron, chiefly consisting of an oxide of that metal, with a small proportion of quartz and alumina, has the power to attract iron. This ore is called the *native magnet*, or *loadstone*. It was originally found in the country of Magnesia in Asia, whence it is supposed to have its name; but it abounds in mines in various other parts of the world. The principal varieties are called by mineralogists, natural loadstone, earthy loadstone, and magnetic iron ore, all which are oxides of iron. Meteoric iron, principally composed of metallic iron and nickel is in general found to be strongly magnetic.

It does not appear that the ancients availed themselves of the magnet for any useful purpose, and it is uncertain at what period it was first applied to its most important use in the Mariner's Compass. This instrument is said to have been introduced into Europe from Asia, in the 12th or 13th century. Its inventor, like most of the early benefactors of mankind, is unknown.

The most important discoveries in Magnetism previous to the present century, were, the variation of the needle, observed by Columbus in 1492, and by Sebastian Cabot in 1497; the dip of the needle, by Robert Norman in 1576; the change of the line of variation, by Henry Gellibrand in 1622; the diurnal variation, by George Graham in 1722; The action of one magnet on another is regulated by a law first discovered by Mayer in 1760, and afterwards by Lambert; it is inversely as the squares of the distances, as proved by Coulomb.

The magnetic property may be communicated to steel by touching it with a natural magnet (or loadstone,) or it may be imparted by a variety of other methods, as by friction with other magnetic bodies, or by percussion. A bar of hard steel held in the direction of the dip of the magnetic needle will become a magnet on receiving a few smart blows on its upper extremity. Now supposing we had no artificial magnets, we might obtain them by taking bars of iron and hammering them while in a vertical position. The lower end would acquire a northern polarity, the upper a southern, and this is the result of the inductive influence of terrestrial magnetism. Small magnets may be formed by simple juxta-position.

When we speak of the *poles* of a magnet, we mean those points where the directive power is concentrated, which in bar magnets centrally suspended, is usually at the ends, that end which points to the north, being called the north pole, that to the south, the south pole. The whole of a magnet possesses the magnetic power, but the force decreases towards its centre, and is then at its minimum.

Both poles of a magnet attract iron, which in return attracts either pole of the magnet. The action of the magnet on iron is confined to attraction; but the action of magnets on each other is characterized by a repulsive as well as attractive force. A north pole *repels* a north pole, and a south pole *repels* a south pole; but a north and south pole mutually *attract* one another, which proves that there are two distinct kinds of magnetic forces, directly opposite in their effects, though similar in their mode of action.

Steel, when touched with a magnet, acquires permanent magnetism; but *soft iron*, although it acquires magnetism more rapidly than steel, loses it as quickly on the removal of the magnet by which it has been touched. The same mechanical means which develope magnetism, will destroy it. On that account a steel bar may lose its magnetism by any mechanical concussion, such as a blow with a hammer, and heating to redness, which reduces the steel to the state of soft iron. Magnets may on the other hand be strengthened by an attention to the converse of these statements. When it is required to unite two or three magnets, so that they may act as a single magnet, they are bound together by a piece of soft iron, which considerably increases their magnetic power. The most powerful attraction in magnets takes place when both poles can be applied to the surface of a piece of iron at once. It is on this account that artificial magnets are often bent into the form of a horse-shoe. The piece of iron which is brought in contact with the poles of the magnet is called an *armature*, or *keeper*.

From this sketch of some of the phenomena of ordinary magnetism, it is not easy to perceive that it was possible for the researches of philosophers to discover in this agent a motive power for machinery, the developement of which should create a new era in mechanics. When however we shall have given a brief view of *Electricity*, and traced the connection between that science and *Magnetism*, as deduced by the splendid discoveries of the philosophers of the present century, we shall be able to realize the importance of the new discovery of Electro-Magnetism ; which in the language of an eminent English writer, is " the most interesting science of modern times, whether it be considered as leading us a step further in generalization, by identifying two agencies hitherto referred to different causes, or as developing a new force unparalleled in the system of the world, which, overcoming the retardation of friction, and the obstacle of a resisting medium, maintains a continuous motion."

ELECTRICITY.

The term Electricity has in the present day a much wider signification than was given to it at any former period. The science, even in its most restricted sense, was quite unknown to the ancient philosophers, and has only recently received an adequate attention from the students of nature. It is true that Thales, Theophrastus, Pliny, and others of the learned Greeks and Romans were acquainted with one electrical phenomenon, but they had not the most remote idea of the agent that produced it, much less of its extensive distribution, and its general influence upon bodies. In the writings of these philosophers, it is stated that *amber* has the property, when rubbed, of attracting small pieces of straw, and other light substances. Amber, which is a translucent substance, chiefly yellow, supposed to be of vegetable origin, though it occurs as a mineral, is termed *electron* in Greek, and the term electricity is derived from it. Thales of Miletus, founder of the Ionic school, ascribes its mysterious power of attracting and repelling light bodies, to an inherent soul or essence, which, awakened by friction, went forth and brought back the small particles floating around. This is the first physical fact recorded in the history of science, and was almost the only phenomenon known in electricity till the year 1600, when Doctor William Gilbert, an English physician, published a work on *Magnetism*, in which he mentioned several new facts attributable to electrical agency, drew the attention of philosophers to this long neglected object of investigation, and thus became the founder of one branch of the science of Electricity. Since this period, our knowledge of this agent has been progressively increasing, and phenomena, which were considered to originate from distinct causes, have been proved analogous or identical.

For a long time it was supposed that the agent called Elecricity could be excited only by friction, and at that time all the phenomena produced by this agent, thus excited, were classed together under the general term, Electricity. But it has since been discovered that it may be influenced and set free by the combination of metallic contact and chemical action, by the contact and disunion of the poles of a magnet, by the circulation of heat through metals, and by the muscular action of certain fishes. This extension of the science has made a subdivision necessary, and hence we have the subordinate sciences of *Common*, or ordinary, *Voltaic* (or *Galvanic*) *Magneto*, *Thermo*, and *Animal* Electricity.

So rapidly have facts been discovered in our own day, that it has been difficult for those who have not paid an almost undivided attention to the subject, to keep pace with discovery. "It is highly probable," says Sir John Herschel, "that we are still ignorant of many interesting features in electrical science, which the study of the Voltaic circuit (or Galvanism) will one day disclose. To Electricity the views of the physical inquirer now turn from almost every quarter, as to one of those universal powers which Nature seems to employ in her most important and secret operations. This wonderful agent, which we see in intense activity in *lightning*, and in a feebler and more diffused form traversing the upper regions of the atmosphere in the *northern lights*, is present, probably, in immense abundance, in every form of matter which surrounds us, but becomes sensible only when disturbed by excitements of peculiar kinds. The most effectual of these is friction, a powerful source of heat."

ORDINARY ELECTRICITY.

The effects produced by Electricity generally are similar to those which would be obtained from the action of a subtle fluid, and hence it is we speak of the *Electric Fluid*. As water, when pent up by some powerful resistance, sweeps away all lesser obstacles when the greater is removed, and flows on until it attains a uniformity of surface, so the accumulated and the confined electric fluid, when it has a means of escape, rushes from its place of rest, and instantly restores equilibrium.

As experience shows that bodies in one electric state attract, and in another repel each other, the hypothesis of two kinds called *positive* and *negative* electricity, is adopted.

The attractive power is exactly equal to the repulsive force at equal distances, and, when not opposed, they coalesce with great rapidity and violence, producing the electric flash, explosion, and shock ; then equilibrium is restored and the electricity remains latent till again called forth by a new exciting cause. Although no substance is altogether impervious to the electric fluid, nor is there any that does not oppose some resistance to its passage, yet it moves with much more facility through a certain class of substances called conductors, such as metals, water, the human body, &c., than through atmospheric air, glass, silk, ivory, &c., which are therefore called nonconductors.

Bodies surrounded with nonconductors are said to be insulated, because, when charged, the electricity cannot escape; but when that is not the case, the electricity is conveyed to the earth, which is formed of conducting matter: consequently it is impossible to accumulate electricity in a conducting substance that is not insulated. Copper, iron, or other wire is generally insulated for electrical purposes by being wound with cotton thread or other nonconductors; the metals being conductors. A body charged with electricity, although perfectly insulated, tends to produce an electric state of the opposite kind in all bodies in its vicinity; positive electricity tends to produce negative electricity in a body near it, and *vice versa*, the effect being greater as the distance diminishes. This power, which electricity possesses, of causing an opposite electrical state in its vicinity, is called *induction*. Electricity may be transferred from one body to another, in the same manner as heat is communicated, and like it, too, the body loses by the transmission. (The analogy, in this particular, does not extend to magnetism.)

It is found by experiment that a metallic globe or cylinder contains the same quantity of electricity when hollow that it does when solid; therefore electricity is entirely confined to the surface of bodies, or if it does penetrate their substance, the depth is inappreciable. The power of retaining electritricity depends also upon the shape of the body. It is most easily retained by a sphere, next to that by a spheroid, but it readily escapes from a point; and on the contrary, a pointed object receives it with most facility. Electricity is evolved by bodies passing from a liquid to a solid state, also by the production and condensation of vapour, which is consequently a great source of atmospheric electricity.

Such are some of the principal facts respecting common or ordinary electricity, as developed by the experiments and observations of philosophers, principally since the year 1600.

Of these philosophers Dr. Gilbert may be considered the first. During the 17th century the subject of electricity was further investigated by Boyle, Otto Guericke, Sir Issac Newton, and others. Guericke of Magdeburg, invented the electrical machine, since improved upon by others. Sir Isaac Newton, in 1675 discovered the fact that glass is capable of excitement by friction; and Dr. Hawksbee, early in the last century, made some successful experiments which led to the discovery of Mr. Stephen Grey of London, between 1720 and 1736. The latter ascertained that some bodies should be considered as conductors, and others as nonconductors of electricity. He also made some experiments which induced him to believe that certain bodies could be excited by friction, while others could under no circumstances be made to possess the attractive power: and, consequently, he divided all substances into electrics and non-electrics. In 1746 the Leyden Jar for the accumulation of electricity was invented at Leyden in Holland. In the same year it was observed that electricity disturbs the position of the magnetic needle. This fact is mentioned by a writer in the Philosophical Transactions. In 1752 Doctor Franklin made his brilliant discovery that lightning is an electrical phenomena. This fact he ascertained by an experiment with a paper kite, during a thunder storm, at Philadelphia, in June, 1752. Franklin immediately proposed the practical application of his discovery by the introduction of metal conductors as a security to buildings against the effects of atmospheric electricity. Science is also indebted to Dr. Franklin for a theory of electricity, which, with some modifications, is still adopted as affording the most satisfactory mode of explaining the phenomena. The fact should here be mentioned, also, that when Franklin was studying the analogy between the operations of atmospheric electricity and that of the electrical machine, his attention was drawn to a consideration of its *magnetic* influence, and he discovered that substances containing iron were rendered magnetic by electricity. He observed that by transmitting the charge of four electric jars through a sewing needle, it became possessed of magnetic properties. Thus it appears that this great philosopher had a glimmering of that light which has since burst upon the world by subsequent discoveries, which have established the identity of electricity and magnetism.

The aurora borealis is an electrical phenomenon, and is well known to produce a disturbance of the magnetic needle during its presence, a phenomenon first observed by Professor Wargentin, in 1750.

The chemical effects of ordinary electricity were discovered by Dr. Priestley, Mr. Cavendish, and others, during the last century. The experiments recently made by Mr. Faraday to determine the same effects are by far the most important. Among the effects produced by electricity when accumulated, most of which we have mentioned in this sketch, are the attraction and repulsion of light substances, the deflection of the magnetic needle, the formation of magnets by its passage through steel, and the production of chemical action on certain compound bodies, and of light and heat in some instances, as well as the excitation of nervous and muscular power when acting upon the animal system. By all these effects the presence of the electric agent may be determined.

The general facts stated respecting ordinary electricity may be reduced to the following propositions:

1. Every substance suffers electric excitement by friction, but the worst conductors are the best electrics. Thus glass and the resins, which scarcely conduct at all, are the most susceptible of excitement, and the metals which are the best conductors are the worst electrics.

2. The electricity of bodies so differ in character, that many persons have believed in the existence of two electricities; one of which they call *resinous*, the other *vitreous*; while others have considered substances to give off a *positive* or a *negative* electricity, according to circumstances, a supposition supported by many curious experiments. It matters but little what theory we may adopt, but we may assume that there is an agent or subtle fluid residing in a latent state as a component part of all substances, and called electricity.

Atmospheric electricity arises from an evolution of the electric fluid during the evaporation that is so abundant at the surface of the earth; and clouds probably owe their existence, or at least their form, to it, for they consist of hollow vesicles of vapour coated with electricity; as the electricity is either positive or negative, the vesicles repel each other, which prevents them from uniting and falling down in rain. Should two clouds charged with opposite kinds of electricity approach within a certain distance, the thickness of the coating of electricity will increase on the two sides of the clouds that are nearest to one another; and when the accumulation becomes so great as to overcome the coercive pressure of the atmosphere, a discharge takes place which occasions a flash of lightning. The actual quantity of electricity in one part of a cloud is extremely small; the intensity of the flash arises from the very great extent of surface occupied by the electricity, so that the clouds may be compared to enormous Leyden jars thinly coated with the electric fluid, which only acquires its intensity by its instantaneous condensation.

Shooting stars are attributed to the passage of electricity in the farthest limits of our atmosphere, in the space between the region of the aurora borealis and the lightest clouds. It is probable that many other atmospheric phenomena are attributable to the electric agent.

VOLTAIC ELECTRICITY, (OR GALVANISM.)

The experiment which first led to the establishment of the science of Voltaic Electricity, (sometimes called Galvanism,) was made by accident in 1790, by Galvani, Professor of Anatomy of the University of Bologna in Italy; by whom it was afterwards investigated, and whose name became attached to the science itself. This philosopher was, it appears, making experiments to prove a theory he had adopted, that electricity is the cause of muscular motion. Some dead frogs were on the table near an electrical machine which was in action. Galvani happened to touch, at this time, a certain nerve of one of the frogs and observed an immediate contraction of its limbs. This singular result seemed so favourable to his theory, that Galvani made farther experiments and published the result of his inquiries. He ascribed these convulsions in the limbs of animals to an electrical fluid or power innate in the living frame, or capable of being evolved by it, which he denominated *animal electricity.* It is curious to observe how nearly Galvani was led, in his investigations, to the truth; but, with a mind already strongly prepossessed in favour of a particular theory, it is not singular that he should have passed by the most important fact developed in his experiments, that the contractions were greatest when the muscles of the animal were connected by two dissimilar metals.

The experiments of Galvani excited the attention of the most noted philosophers of Europe, who repeated them in various ways, adopting their own theories to explain the phenomena. At the commencement of the year 1793, two letters from Professor Volta, of Pavia in Italy, were read before the Royal Society of London. In these communications he expressed his entire dissent from all the theories that had been proposed to account for the physiological effects referred to. He admitted that the agent was electricity, but could not allow it to be obtained from the animal body. He concludes that the contractions are produced by a disturbance of electric equilibrium. The mere contact of the metals, he states, does disturb their electricities, and the frog being in the circuit of the fluid, is, in fact, nothing more than a delicate electrometor. His opinions were confirmed by observing the effects of electricity on living animals, and particularly by applying a plate of silver and another of zinc to the upper and lower surface of his tongue.

Looking at the science of galvanism in its present state, with the mind occupied by all the accumulated evidence of modern research, it is almost impossible to form an estimate of the close perception of facts and the ingenuity of Volta, in thus rejecting the theories of his contemporaries and introducing one which, at first sight, seems so improbable, although since proved to be correct. It is, therefore, with great justice and propriety that this science has received the name of *Voltaic electricity*, in honour of this celebrated philosopher.

In subsequent experiments, Volta farther discovered, that other dissimilar bodies besides metals, were capable, by contact, of disturbing the electrical equilibrium.

Since a slender rod of silver, and one of zinc, touching each other at one of their ends, and at the other brought into contact with the nerve and muscle of a dead frog, could excite powerful convulsions, it occurred to Volta, that a repetition, on a more extended surface, of that simple series of two metals and moisture, might produce a combined effect capable of being felt by the human hand. By a most philosophical prosecution of his own principle, he happily succeeded in constructing by regular alternation of discs of silver, zinc, and moistened cloth, or pasteboard, reared in a columnar form, the electro-chemical pile and battery, (called the Voltaic pile) which will associate the name of Volta with that of Galvani, through each succeeding age. It was thus, by a series of experiments and observations, that he had arrived at the knowledge of a general fact, that of the disturbance of electrica equilibrium by the mere contact of different bodies, and the circulation of a current of electricity in one constant direction through a circuit, composed of three different conductors, (such as two metals and one fluid.)

"Nor did his inquiry terminate," says Herschel, "till it had placed him in possession of that most wonderful of all human inventions, the pile which bears his name, (just described,) through the medium of a series of well conducted and logically combined experiments which has rarely if ever been surpassed in the annals of physical research."

The Voltaic Pile, (or battery,) was described by Volta himself, in a letter to Sir Joseph Banks, then president of the Royal Society, in 1800. It has frequently happened in the annals of science, that a great improvement, or discovery has been made simultaneously, by persons who have had no means of intercourse, but whose attention has been called, by facts, to a particular investigation. Volta, however, enjoyed the exceeding pleasure of knowing that there was no rival for his fame; none with whom he was compelled to divide his laurels.

Volta, finding the columnar form of his apparatus inconvenient in some respects, invented another, which was called the *Couronne de Tasses*, or Chain of Cups. It consisted of metallic arcs of copper and zinc, with which he connected a circle of cups containing salt water, thus forming a horizontal, instead of a columnar arrangement. Mr. Cruickshanks was the inventor of that arrangement or modification of the Voltaic pile, called the *Voltaic Trough;* or as it is also termed, the Galvanic Battery. It consists of copper and zinc plates cemented into a water-tight trough of well-seasoned wood. A copper plate terminates the series at one end, and a zinc at the other, as in the pile. When the instrument is to be put in action, the trough is filled with water containing a small proportion of sulphuric acid. Another construction has since been adopted by experimenters, in which the plates are so arranged, that they may be removed from the trough when the instrument is not wanted, and its energy be consequently preserved.

Various other forms of Voltaic or Galvanic batteries have been invented and applied in Europe and the United States. Doctor Hare of Philadelphia has invented two; one called the *deflagrator*, and the other the *calorimotor*. The former is composed of two troughs, one of which is to receive the acid, when the action of the deflagrator is to be suspended. Many important experiments have been made by Doctor Hare with this apparatus. The *calorimotor*, in which a great quantity of heat, accompanied by little electrical *tension*, is produced, consists of such an arrangement, as to form one pair of separate plates; for all the zinc plates in one half of the apparatus being connected together by a metallic strap, constitute but one plate, while all the copper ones being united, form another. The plates being arranged in alternating series, so as to present their surfaces to each other. Dr. Hare regards this instrument as furnishing an extreme case of great heating power with low electric intensity.

Every Galvanic combination, or Voltaic circle, must consist of three elements; and one of these must be a solid, the second a fluid; the third may be either a solid or a fluid. Of all the solid elements capable of forming Galvanic combinations, the metals and charcoal are the most efficacious. Of fluid elements, those which produce the greatest chemical action upon the solids, are to be preferred, such as the mineral acids, alkaline solutions, sulphurets, and solutions of neutral salts.

For the developement of electricity, it is necessary that the three elements should form a circle. Thus, if a plate of copper and zinc be in contact at one of their extremities, the other being immersed in a diluted acid, a Galvanic circle will be formed. There will here be a current of positive electricity, passing from the zinc to the acid; from the acid to the copper; and from the copper to the zinc; and there will also be a current of negative electricity circulating in the opposite direction, from the zinc to the copper; from the copper to the acid; from the acid to the zinc. This effect is produced only when the metals are in contact: as soon as they are separated the current ceases. A communication may be established between them by a metallic wire, or two wires, one attached to each plate, and we shall still have a Voltaic combination.

The arrangement we have described, is the one commonly employed, namely, copper, zinc, and diluted acid: but a great variety of other substances may be used. Bearing in mind, the principle to which we have already alluded, that chemical action must be developed, any substances may be employed, manifesting analogous effects with metals and acids, though in most cases with far inferior energy.

Lagrave has stated that he formed a Galvanic arrangement by alternate layers of muscle and brain, with pieces of moistened cloth interposed. Other experimenters have also used animal substances. Dr. Baconio of Milan, made a Voltaic pile of vegetable substances, using disks of red beet root, two inches in diameter, and similar disks of walnut tree, the latter deprived of their resinous matter, by masceration in a solution of cream of tartar in distilled vinegar. With such a pile, using a leaf of scurvy grass, as a conductor, he is stated to have produced contractions of the muscles of a dead frog. Professor Zamboni of Verona, made a pile with disks of paper, gilt on one side, and coated on the other with layers of black oxide of manganese made into a paste with honey. The most simple arrangement of this kind is that called De Luc's electric column, consisting of disks of paper, covered with gold or silver leaf, and similar disks of laminated zinc properly arranged. With two upright electrical columns like these connected at the tops, and a brass ball suspended between them, De Luc caused the continued ringing of two small bells, for a series of years.

Among the crowd of philosophers who have followed Galvani and Volta, in this science, two are pre-eminent for the ingenuity and success of their investigations, viz: Dr. Wollaston and Sir Humphry Davy. The first had the merit of tracing up the analogy between the mysterious operations of Voltaic and of common electricity. The discoveries made by Sir H. Davy in Voltaic electricity, and its application to chemistry, probably surpass in importance, as they do in splendour, the united discoveries of preceding chemists. His examination of the subject, ultimately led him to the discovery of the bases of the alkalies, and those other brilliant results which have conferred honour on his name. Dr. Faraday, who succeeded Sir H. Davy in the public institution with which he was so long connected, has continued the researches he commenced, and has been singularly successful in his investigations.

There are, says Dr. Ure, six great eras in electro-chemical science: — 1st, Its first discovery by Galvani; 2d, Volta's discovery of the contact of dissimilar metals disturbing the electric equilibrium; 3d, Volta's invention of the pile; 4th, the *chemical* power of this instrument, first observed by Messrs. Carlisle and Nicholson, in the decomposition of water; 5th, the identity of these chemical effects with those of common electricity, by Dr. Wollaston; and 6th, the general laws of electro-chemical decomposition and transfer, revealed by Sir H. Davy, in a series of memoirs, remarkable for genius and industry, commencing in the year 1800.

The effects of Voltaic electricity are classed under the general heads, *physiological, chemical, luminous, heating*, and *magnetic*.

The *physiological* effects resulting from the passage of Voltaic electricity through the animal body were the means, as we have stated, of introducing the agent itself to the attention of philosophers.

Many experiments have been since made in this and other countries, upon the bodies of animals immediately after their execution, in which the powerful effects of Galvanism upon the muscles and nerves have been shown. Every kind of animal appears to be susceptible of the influence of Voltaic electricity; fishes and worms are peculiarly sensitive. Living bodies are acted upon by this agent, as well as those which are recently dead. With a single pair of metallic plates, however large, no violent physiological effect can be obtained. So on the other hand, a number of plates, however small, and containing not one-twentieth part of the metal in the single pair, may give a violent shock. The administration of Voltaic electricity as a medical agent, has been found beneficial in some diseases.

The attention of electricians has been recently drawn to the remarkable appearance of certain insects during the performance of some experiments on electrical crystallization, by Mr. Crosse in England.

Some specimens of these insects were sent by the Royal Society to the French Academy, and according to the report drawn up by some of the members, they belong to a new species of the genus *Acarus*.

The *chemical* powers of the Voltaic battery have afforded the means for some of the most remarkable discoveries of modern times, among which it will be sufficient to mention the decomposition of potash and soda, and the earths, and the exhibition of their metallic bases, by Sir Humphry Davy. Numerous other instances might be given, but the decomposition of water is perhaps the most simple and elegant. The powerful efficacy of Voltaic electricity in chemical decomposition arises from the continuance of its action. But it is now proved to be as efficacious in the composition as in the decomposition, or analysis, of bodies.

M. Becquerel has succeeded in forming crystals of a great proportion of the mineral substances precisely similar to those produced by nature. A method of galvanising metals to prevent oxidation has been recently discovered in Paris, and patented in France, England, and the United States.

When the battery is powerful, the *luminous* effects of Galvanism are very brilliant. Its transit is accompanied by light; and in consequence of the continuous supply of the fluid, sparks occur every time the contact of the wires is either broken or removed. The most splendid artificial light known, is produced by fixing pencils of charcoal at the extremities of the wires, and bringing them into contact. This light appears to be independent of combustion, since the charcoal suffers no change. It differs from the solar light in possessing some rays of which the sun beams are deficient.

It is thought by some persons that the Voltaic light will be, at some future period, applied in those cases where a strong and brilliant illumination is required. Should electricians succeed in using this agent for such purposes, it will be well suited for light-houses, and also, perhaps, for the illumination of large buildings and cities.

The *calorific*, or *heating* effects of Voltaic electricity are far greater than those of the common electrical machine. Instead of a momentary evolution, which seems to arise from a forcible compression of the particles of matter during the passage of the common electric fluid, the circulation of the Voltaic electricity is accompanied by a continued developement of heat, lasting as long as the circuit is complete, without producing either light or sound. Its intensity is greater than that of any heat that can be obtained by artificial means, so that it fuses metals, and substances which resist the action of the most powerful furnaces. The order in which metallic wires are raised to a red heat by Galvanism, is ascertained to be as follows: platina, iron, copper, gold, zinc, and silver. The facility with which the metals are ignited, varies inversely as their conducting power for electricity.

The power of a Voltaic battery in the production of heat depends upon the quantity of electricity that is transmitted through the wire, rather than its intensity. It was for this reason that Dr. Hare constructed the battery, already mentioned, of a single pair of plates, (or number of plates so united as to form a pair,) and from its great heating power, called a *calorimoter.*

The *magnetic* effects of Voltaic electrictity and the relations of electric and magnetic currents, will be more properly explained under the head of *Electro-Magnetism ;* we may now however mention a few elementary facts.

Arago proved some years since, that a bar of steel may be magnetised by a current of Voltaic electricity. If a sewing needle, for instance, be placed across a conducting wire, it will acquire the magnetic property, or polarity. Supposing the wire to be placed before the experimenter, the zinc end of the battery being to his left hand, the point of the needle most distant from him will be the north pole when above the conducting wire, and south when below. A needle may also be magnetised by placing it in a spiral conducting wire or helix.

The effects of electricity in motion are not only precisely the same as the reciprocal action of magnetised bodies, but its influence in inducing magnetism in unmagnetised iron and steel is also the same with magnetic induction. The term induction, when applied to electric currents, expresses the power which these currents possess of inducing any particular state upon matter in their immediate neighbourhood, otherwise neutral or indifferent. For example, the connecting wire of a Galvanic battery holds iron filings suspended like an artificial magnet, as long as the current continues to flow through it; and the most powerful temporary magnets that have been made, are obtained by bending a thick cylinder of soft iron into the form of a horse-shoe, and surrounding them with coils of thick copper wire, covered with silk or cotton, to prevent communication between its parts. The iron loses its magnetic power the instant the electricity ceases to circulate, and acquires it again as instantaneously when the circuit is renewed.

MAGNETO-ELECTRICITY.

From the law of action and reaction being equal and contrary, it might be expected that as electricity powerfully affects magnets, so conversely magnetism ought to produce electrical phenomena. By proving this very important fact from a series of interesting and ingenious experiments, Dr. Faraday has added another branch to the science, which he has named Magneto-Electricity. In 1831, this philosopher succeeded in producing momentary electrical effects from a common steel magnet. He found that when a helix or spiral of copper wire is brought near the poles of a powerful magnet, electrical currents are excited in it. These are increased by inserting a bar of soft iron within the helix. The identity of these currents with the electricity of the machine and battery, is proved by the production of sparks, the heating of metallic wires, chemical decomposition, the shock, and other effects commonly resulting from the electric fluid. The electric spark has been obtained from the natural magnet or loadstone, as well as the steel magnet; and Mr. Saxton of Philadelphia, invented a machine for concentrating and developing electricity from steel magnets, on a principle which has been much approved and adopted, with some improvements, by others.

Mr. Saxton's instrument consists of powerful horse-shoe steel magnets, placed in a horizontal position. Close to the poles of the magnet there is fixed an iron armature, so formed that its two ends may be brought in contact with them. The armature is made to rotate by a suitable wheel, and a current induced by an alternate contact with an arrangement of wires and mercury.

THERMO-ELECTRICITY.

Professor Seebeck of Berlin, in Prussia, in 1822 discovered that electric currents may be produced by the partial application of *heat* to a circuit formed of two solid conductors. This branch of the science is called *Thermo-Electricity*. The Professor named above found that when a brass wire was coiled around the ends of a bar of antimony, and heat applied at one extremity, magnetic action was developed. Or when a semi-circle of bismuth, joined to one of antimony, so as to form a ring, is heated at one of the junctions by a lamp, a current of electricity flows through the circuit, producing electro-magnetic effects. Nobili says the same substance unequally heated, exhibits electrical currents.

All the effects produced by ordinary and Voltaic electricity have now been obtained by the Thermo-electric currents, though philosophers were long foiled by the small intensity of the fluid.

ANIMAL ELECTRICITY.

This term has been applied to many distinct classes of phenomena. The free electricity of the human body has been sometimes so called, and at one period Galvanism had the same name. It seems proper, however, to confine the use of the expression to that agent developed by a few fishes called the *electrical fishes*. Of these the most remarkable are the *Gymnotus Electricus*, or Electric Eel, found in South America, and the *Torpedo*, a species of ray, frequent in the Mediterranean and some other seas. The absolute quantity of electricity brought into circulation by the torpedo is so great that it affects the decomposition of water, has power sufficient to make magnets, and gives very severe shocks. It is identical in kind with that of the Galvanic battery, the electricity of the under surface of the fish being the same with the negative pole, and that in the upper surface the same with the positive pole. The shock may be conveyed through an iron rod or wet line, but not through nonconductors. The electric spark has also been obtained from the Torpedo.

Three other kinds of electrical fishes have been mentioned besides the foregoing, and are found in the river Nile, the Indian Seas, and off the Island of Joanna, on the eastern coast of Africa.

There are then, as we have described, five sources of electricity, viz: Common, Voltaic, Magnetic, Thermal, and Animal Electricity; not five distinct kinds, as some suppose, but the same agent in different states. By bearing in mind the unity of the agent, the inquirer will be greatly assisted in acquiring a knowledge of the science.

In light, heat, and electricity, or magnetism, nature has exhibited similar principles, and these agencies are so connected that there is reason to believe they will ultimately be referred to some one power of a higher order, in conformity with the general economy of the system of the world, where the most varied and complicated effects are produced by a small number of universal laws.

ELECTRO-MAGNETISM.

A CONSIDERATION of the facts and phenomena which we have given in the preceding sketch, will prepare us to understand the nature of the connection between electricity and magnetism, as deduced from the researches of philosophers within the last twenty years, which have given rise to, and established, the science of *Electro-Magnetism*.

Of all the philosophers who had speculated on the subject of a relation existing between magnetism and electricity, none had so pertinaciously adhered to the idea of a necessary connection, as Professor Oersted of Copenhagen, in Denmark. "Baffled often, he returned to the attack; and his perseverance was at length rewarded by the complete disclosure of the wonderful phenomena of Electro-Magnetism. There is something in this," says Sir John Herschel, "which reminds us of the obstinate adherence of Columbus to his notion of the necessary existence of the new world; and the whole history of this beautiful discovery may serve to teach us reliance on those general analogies and parallels between great branches of science by which one strongly reminds us of another, though no direct connection appears; as an indication not to be neglected of a community of origin."

The first successful experiment made by Professor Oersted, showing the power of electric currents to induce magnetism, was in the year 1819, in the presence of a class of his students. By this experiment he ascertained that an electric current passing along the wire used to connect the extremities of a Galvanic battery, possesses power to deflect the magnetic needle in a remarkable manner. If this wire, conveying a positive electric current from north to south, be placed horizontally over the needle, and therefore parallel to it, the north pole of the needle is turned toward the *east*. If the wire be placed in like manner below the needle, the same pole is carried toward the *west*. If it be removed to the east side, the pole is depressed; if to the west, it is elevated. The effects produced by a similar current on a south magnetic pole, are precisely the reverse. Accordingly, since in the rotation of a needle suspended by its centre, the two ends move always in opposite directions, both forces conspire to increase the effect produced upon it by a single electric current.

These phenomena are precisely such as would be produced by a rotary or circular force, referred to the wire as an axis. As the magnetic pole, acted upon by this force, is moved in a tangent to the circle, the force has itself been called *tangential*. All the experiments in this science, tend to prove that the force emanating from the electric current, which produces such effects on the magnetic needle, acts at right angles to the current, and is therefore unlike any force hitherto known.

Professor Oersted's discovery, which in its practical consequences bids fair to rank among the first in importance ever made in philosophy, at once aroused the curiosity and stimulated to activity the ingenuity of the whole philosophic world. M. Arago and Sir Humphry Davy soon discovered that the connecting wire of the battery, besides exerting an apparently repulsive power upon a magnetic pole, exhibited also during the passage of the current, the ordinary magnetic attraction upon iron and steel, in a high degree. Thus the wire would sustain a mass of iron filings, of a dozen times its own diameter, but these instantly fell away, on the cessation of the current. The philosopher last mentioned, found that steel needles became magnetic by the Galvanic current. The *induction* of magnetism by electricity was thus early demonstrated.

From a consideration of the law of tangential force applicable to Electro-Magnetism, as we have explained, Doctor Wollaston suggested that the pole of a magnet, free to move in any direction, and prevented from so far obeying the centrifugal force as to be thrown beyond the influence of the electric current, ought to revolve in a circle about the conducting wire. This inference was practically confirmed by Professor Faraday, by the following experiment. In order to limit the action of the electricity to one pole, about two-thirds of a small magnet was immersed in mercury, the lower end being fastened by a thread to the bottom of the vessel containing the mercury; when the magnet was thus floating almost upright with its north pole above the surface, a current of positive electricity was made to descend perpendicularly through a wire touching the mercury, and immediately the magnet began to revolve from left to right about the wire. Under the same circumstances, the south pole of the magnet rotates from right to left. The motion continues as long as the current lasts. The magnet being fixed, and the conducting wire provided with a joint, the latter was made to revolve about the magnet, and even a small battery consisting of two plates, has performed the rotation. Mr. Faraday caused both the wire and the magnet to revolve at the same time, (in a vessel containing mercury,) in one direction about a common centre of motion.

The next step was to make a magnet and also a cylinder revolve about their own axes, which they do with great rapidity. Mercury was made to rotate by means of Galvanism. Professor Ritchie has exhibited the singular spectacle of the rotation of water, by the same means, while the glass vessel containing it, remained stationary. But one of the most extraordinary effects of the new force, is exhibited by coiling a copper wire so as to form a helix or spiral, and connecting the extremities of the wires with the poles of a Galvanic battery. If a magnetised steel bar or needle be placed within the spiral or screw, so as to rest upon the lower part, it starts up by the influence of this invisible power, and remains suspended in the air in opposition to the force of gravitation. The effect of the Electro-Magnetic power exerted by each turn of the wire is to urge the north pole of the magnet in one direction, and the south pole in the other; and in consequence of these opposing forces, the steel bar remains suspended. This helix or spiral of wire, has all the properties of a magnet, while the electrical current is flowing through it, and may be substituted for one in many experiments. It acts as if it had a north pole at one extremity, and a south pole at the other; and is attracted and repelled by the poles of a magnet exactly as if it were one itself.

It appears from what precedes, that the principal and characteristic phenomena of the Electro-Magnetic science are the evolution of a tangential and rotary force exerted between a conducting body and a magnet; and the transverse induction of magnetism by the conducting body in such substances as are susceptible of it.

In the year 1825, Mr. Sturgeon of England, magnetised cylindrical horseshoes of soft iron, by means of copper wires wound around them, connecting the ends of the wires with the plates of a Voltaic battery. Professor Van Moll of Utrecht, saw this experiment performed in the London University by Mr. Watkins, and he afterwards by winding insulated wire around soft iron, imparted to it prodigious magnetic power, so that a horseshoe bar thus provided, and connected with a Galvanic battery, lifted over one hundred pounds. In

1830, Professor Henry of Albany, (now of Princeton College,) and Dr. Ten Eyck, by a new method of winding the wire, obtained an almost incredible magnetic force, and made the first Electro-Magnet in the United States, capable of lifting about 750 pounds, with a small battery and a pint or two of liquid ; and they afterwards formed another magnet which sustained 2063 pounds. This magnet consisted of a horse-shoe bar of soft iron, wound with 26 strands of copper bell-wire, covered with cotton thread, the aggregate length of the coils on the iron being 728 feet. The battery used contained less than 48 square feet. Professor Henry has now at Princeton College an Electro-Magnet weighing 100 pounds, which will lift 3600 pounds.

Professor Joslin of Union College, Schenectady, in 1831, made an Electro-Magnet of considerable power, using a rectangular sheet of copper, (insulated with silk,) instead of wire, coiled around the iron. His experiments were confirmed by those of Professors Emmet of Virginia, and Ritchie of London, from which it would seem that wire may be dispensed with in the construction of Electro-Magnets, although it is still generally used.

Wonderful as the immense power thus instantaneously called into action by means the most simple, appears to us, our astonishment becomes still greater when we consider not only that it may just as instantaneously be suspended, or reduced to nothing: but that what was just now *attraction*, may be converted in the twinkling of an eye, into the most powerful *repulsion*. This arises from the fact that the direction of the induced magnetic poles depends on that of the electric current. This current may be reversed in a space of time too minute even for conception, and the poles are reversed along with it. In other words, by reversing the conducting wires of the Galvanic battery connected with an Electro-Magnet, an instantaneous *change of poles* of the magnet is effected, the north pole becomes a south pole, and *vice versa* alternately as often as the electric current is reversed. This fact, of a change of poles, was ascertained from Professor Van Moll's experiments before referred to, subsequent to

1825, and the knowledge of the principle has induced many experimenters to endeavour to turn it to account for the generation of motion. Professor Henry was the first who succeeded, producing, as early as 1831, a reciprocating motion in a horizontal Electro-Magnetic bar.

ELECTRO-DYNAMICS.

The science of Electro-Magnetism, which has been under consideration, relates to the reciprocal action of electrical and magnetic currents. M. Ampere, a celebrated French philosopher, by discovering the mutual action of electrical currents on one another, has added a new branch to the subject, to which he has given the name of *Electro-Dynamics.*

When electric currents are passing through two conducting wires, so suspended or supported as to be capable of moving both towards and from one another, they show mutual attraction or repulsion, according as the currents are flowing in the same or contrary directions; the phenomena varying with the relative inclinations and positions of the streams of electricity.

The phenomena mark a very decided difference between the action of electricity in motion or at rest; that is between Voltaic and common electricity. Since Voltaic electricity flows perpetually, it cannot be accumulated, and consequently has no tension or tendency to escape from the wires which conduct it. Whereas ordinary electricity can be accumulated in insulated bodies to a great degree, and in that state of rest the tendency to escape is proportional to the quantity accumulated, and the resistance it meets with. In ordinary electricity the law of action is, that dissimilar electricities attract, and similar electricities repel one another.

In Voltaic electricity, on the contrary, similar currents, or such as are moving in the same direction, attract one another, while a mutual repulsion is exerted between dissimilar currents, or such as flow in opposite directions. This last mentioned fact is at the basis of the science of Electro-Dynamics. It was a discovery of M. Ampere, made soon after Oersted's experiments were published.

M. Ampere has established a theory of Electro-Magnetism, suggested by the analogy between Electro-Dynamic cylinders and magnets, founded upon the reciprocal attraction of electric currents, to which all the phenomena of magnetism and Electro-Magnetism may be reduced, by assuming that the magnetic properties which bodies possess, derive their properties from currents of electricity circulating about every part, in one uniform direction.

It has been observed that, although every particle of a magnet possesses like properties with the whole, yet the general effect is the same as if the magnetic properties were confined to the surface; consequently, the internal electro-currents must compensate one another, and therefore the magnetism of a body is supposed to arise from a superficial current of electricity constantly circulating in a direction perpendicular to the axis of the magnet; so that the reciprocal action of magnets, and all the phenomena of Electro-Magnetism, are reduced to the action and reaction of superficial currents of electricity acting at right angles to the direction of the currents. Not only has this theory of Ampere's the merit of simplifyng a hitherto mysterious class of phenomena, but it explains many of the remarkable rotations we have described, much more satisfactorily than the supposition of a tangential force could possibly do. This theory has been further confirmed by the experiments and discoveries of Mr. Faraday and others in Magneto-Electricity.

We may conclude, therefore, that the common magnet must be encircled by currents of electricity moving at right angles to its axis; and that the earth itself must be traversed by similar currents passing round it from east to west. That the effect of such currents upon the magnetic needle, would be precisely such as we see actually produced by the influence of terrestrial magnetism, was experimentally demonstrated by Mr. Barlow in 1831, by means of an artificial globe. We may add, that experiments made by Mr. Fox, in the mines of Cornwall, seem to prove the actual existence of such currents in the earth.

APPLICATION OF ELECTRO-MAGNETISM TO THE MOVEMENT OF MACHINERY.

The first application of this power to the movement of machinery, as we have already mentioned, was made by Professor Henry of Princeton College, N.J., in 1831. The account of his successful attempt is recorded in Silliman's Journal of Science, vol. 20, p. 340. The power was applied to the movement of a small machine, by a beam suspended in the centre, which performed regular vibrations in the manner of the beam of a steam engine.

The following are extracts from Professor Henry's communication on the subject, as above stated in 1831.

"I have lately succeeded in producing motion in a little machine, by a power which, I believe, has never before been applied in machinery, by magnetic attraction and repulsion.

"Not much importance, however, is attached to the invention in its present state, although, in the progress of discovery and invention, it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose.

"The motion here described is entirely distinct from that produced by the Electro-Magnetic combination of wires and magnets; it results directly from the mechanical action of ordinary magnetism, Galvanism being only introduced for the purpose of *changing the poles*."

The next Electro-Magnetic machine, and the first having a *rotary motion*, of which we have any record, was invented in 1832, by Mr. William Sturgeon, an eminent experimenter in this science, of Woolwich, near London, and is described in *Sturgeon's Annals of Electricity*, &c. published in October, 1836.

Mr. Sturgeon remarks that "this engine was constructed in the autumn of 1832, and was exhibited, for the first time, in London, on the 21st of March, 1833, in a lecture which I delivered at the Western Literary and Scientific Institute. Since that time, I have attached to it contrivances for drawing wagons, &c. on a railway, for sawing wood, pumping water, &c., upon about the same scale as we see pieces of machinery put into motion by the large models of steam-engines. But as I saw several parts in which it might be improved, it has long since been laid by," &c.

Professor Dal Negro of Padua, in Italy, published in 1832, an account of some experiments made by himself in Electro-Magnetism, by which it appears, that he obtained a vibratory motion in a magnetic steel bar, placed beneath the poles of an Electro-Magnet.

Early in 1833, Dr. Ritchie of London, obtained a rapid rotation of an Electro-Magnetic bar, at first under the influence of a horse-shoe magnet, wide between the poles, and afterwards by the power of terrestrial magnetism alone. The account of this invention was read to the Royal Society on the 21st of March, 1833, and published in their Transactions for that year.

In February, 1833, Doctor Schultess of Zurich, in Switzerland, delivered before the Philosophical Society of that place, a lecture on Electro-Magnetism, in which he describes a machine which he had constructed the previous month, moved by the reciprocating action of an armature of soft iron between two electro-magnets. He remarks, "If we consider that electro-magnets have already been made which were capable of carrying 20 cwt. and that there is no reason to doubt that they may be made infinitely more powerful, I think I may assert boldly that *Electro-Magnetism may certainly be employed for the purpose of moving machinery.*"

It is remarked in Silliman's Journal of Science, (vol. 35, p. 106,) that Doctor Edmondson of Baltimore, was probably the first person in the United States who obtained a *rotary motion* by this power. His machine is described in that Journal for 1834.

Professor Botto of Turin, in Italy, obtained early in 1834 a vibratory motion by Electro-Magnetism in a machine of his construction, an account of which he published in July of that year. There is a great analogy in his arrangement and that of the electrical clock of M. Zamboni, which is put in motion by a pendulum alternately attracted and repelled by the poles of two of the dry piles which bear his name.

In his essay on the subject, Professor Botto expresses his confidence in the application of this power to machinery.

In May, 1834, Professor Jacobi of the University of Dorpat, in Russia, constructed an Electro-Magnetic Engine with a *rotary motion*, an account of which he published at Potsdam, in 1835, with an elaborate essay and account of his experiments. He estimates the power of his machine as equal to half the force of a man, and remarks: "To maintain this action during eight hours, scarcely half a pound of zinc is required, everything being properly arranged. I may perhaps be justified in maintaining that the superiority of this new motor, with regard to the absence of danger, the simplicity of the application, and the expense of the material necessary to keep it in action, is placed beyond doubt."

In July, 1834, Mr. Davenport, a mechanic of Vermont, without knowledge, it is said, of the experiments of others, produced a rotary motion by Electro-Magnetism. After that time he continued to improve in the construction of his machines, until the early part of the year 1837, when he obtained a patent, and during that year exhibited at New-York and other cities, several models of his invention. Some of the models having been shown to Professor Silliman of Yale College, a full account of Davenport's Machine was given by him in his Journal of Science, vol. 32, April, 1837.* Public attention having been much attracted to the subject, other experimenters entered the field, both in this country and in Europe; and the result of some of their labours have been published in various Scientific Journals. Among these should be mentioned a machine made by Doctor B. R. Mc-

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* The principle of Davenport's Machine, viz. rotary motion by a change of poles, appears to be the same as that which had been previously adopted by Sturgeon, Ritchie, and Jacobi.

Connell of Pennsylvania, described in Silliman's Journal of Science for October, 1837. This machine is in principle different from any previous contrivance of the kind, but we have not since heard whether it has been tried on a larger scale than the small model described.

It appeared evident to many that the application of this newly discovered power to practical purposes, could only be tested by a considerable expenditure of funds, in experiments conducted by scientific and mechanical skill, which objects could most probably be accomplished by an association of individuals for the purpose. Some gentlemen have therefore recently obtained an act of incorporation for the *Electro-Magnetic Company*, to whom we are indebted for the first successful application of this power on a large scale, in the Magnetic Engine to which the attention of the public has been recently called, and which is exhibited at the Twelfth Annual Fair of the American Institute.

The motive wheel of this engine is of mahogany, five feet in diameter, and 7½ inches in thickness, weighing about 500 pounds. On this wheel are placed 24 iron bars, or armatures, screwed into the periphery of the wheel. These bars are attracted by the action of four electro magnets, weighing about 75 pounds each, which are placed on a wooden frame, on which the wheel revolves vertically. When the iron bars on the wheel are attracted by the magnets so as to come alternately opposite the poles of the magnets, the magnetism is suspended by a contrivance consisting of revolving disks of copper and ivory on the shaft in the centre of the wheel. The magnets being kept in action by a connection with the wires of a Galvanic battery, the electricity or Galvanism from the battery is cut off or suspended every time the conductor strikes the ivory of the disks, which is 24 times in each revolution of the wheel. The battery is composed of alternate plates of copper and zinc, immersed in a solution of sulphate of copper, sulphuric acid, and water.

Professor Renwick of this city, remarks, that " This engine is more simple in its structure, and possesses a higher degree of power than any I have yet seen in use propelled by the same power. It in consequence appears more promising to be successfully applied to machinery for useful purposes than any which has come within the limits of my observation."

Among the various uses to which this new power may now be applied may be enumerated,—*Printing Presses; Silk, Cotton, Wool, Rope and Twine Manufactories; Turning Lathes, Cabinet and Joiners' works;* also to numerous other mechanical and domestic purposes.

Professor Silliman remarks, in an article on Electro-Magnetism, in his Journal, (vol. 33.)

"Surely there are not wanting men, and we trust they are numerous, who will cheerfully pay the comparatively small sums whose considerable aggregate will carry forward this interesting research, until the ratio and the extent of its power are ascertained: and if it should prove that the limit is far beyond the demands of practical application, so much the better; but neither the ratio nor the extent can be learned without persevering experiments, the expense of making which, and of sustaining all who are concerned in making them, will be, we trust, cheerfully borne by the public."

When it is considered that the science of Electro-Magnetism is of so recent discovery, and has only attracted public attention as a motive power for machinery the last two or three years,* it will not be deemed surprising that more has

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* *Eight years* only have elapsed since motion was first obtained by Electro-Magnetism, and it can now be applied to machinery.

In 1663, the Marquis of Worcester invented his steam engine, and showed that steam could be used as a motive power. More than *one hundred years* afterwards, viz. in 1769, Mr. Watt obtained his patent for the modern steam engine. The first steam engine in Manchester was erected in 1789. The first American steam-boat in successful operation was built by Fulton in 1807, and the first vessel successfully propelled by steam in Great Britain was the Comet of Glasgow, in 1812.

Those who are best acquainted with the steam engine, have expressed opinions that Electro-Magnetism will eventually prove a *substitute for steam.*

The distinguished Dr. Lardner of London, in one of his essays on the steam engine, remarks as follows:

"Philosophy already directs her finger at sources of *inexhaustible power* in the phenomena of *Electricity* and *Magnetism,* and many causes combine to justify the expectation that we are on the eve of mechanical discoveries still great-not yet been accomplished. It is believed, however, that the time for its successful application on a large scale is rapidly approaching. In the language of Professor Silliman, "it is much to be desired that the investigation should be prosecuted with zeal, *aided by correct scientific knowledge*, by *mechanical skill*, and by *ample funds*." These important requisites, one or more of which, we believe, have been heretofore wanting, it should be the object and design of an Electro-Magnetic Company to combine; thus uniting capital with science and art.

Professor Morse of this city, who has invented an Electro-Magnetic Telegraph, for which he recently received the medal of the French Institute in Paris, expresses the following opinion respecting the machine belonging to the Electro-Magnetic Company:

> "I take pleasure in giving you in writing, what I have frequently observed in conversation, respecting the Electro-Magnetic Machine now in operation in Gold-street, No. 58. The application of the magnetic power in this machine, produces greater effects than in any arrangement I have yet seen, and I do not perceive any insurmountable obstacle to the indefinite increase of these effects.
>
> SAMUEL F. B. MORSE.
>
> NEW-YORK CITY UNIVERSITY, June 8, 1839."

er than any which have yet appeared; and that the *steam engine* itself with the gigantic powers conferred upon it by the immortal Watt, will dwindle into insignificance, in comparison with the hidden powers of nature still to be revealed, and that the day will come when that machine which is now extending the blessings of civilization to the most remote skirts of the globe, will cease to have existence except in the page of history."

Mr. Tredgold, in his celebrated Treatise on the Steam Engine, (vol. 1, p. 45,) has the following remarks:

"Probably some other source of power will be discovered, which will divert the attention of projectors, and the only one in nature which appears unemployed by man, seems to be that of the *Electric Fluid;* how far it may be rendered useful is a matter of curious inquiry."

EXPERIMENTS

AND

OPINIONS OF SCIENTIFIC MEN, SHOWING THAT

ELECTRO-MAGNETISM

MAY BE APPLIED AS A MOTIVE POWER TO MACHINERY.

Remarks by Professor Jacobi of the University of Dorpat, (Russia,) in 1835.

"The great discovery of M. Oersted, which has so much extended the limits of physical science, promises to open a new career to practical mechanics. Magnetism enables us to employ immediately a force; the point of application is the force itself. The study of the phenomena of electricity and magnetism is still in its infancy, and we are not surprised that every day makes us acquainted with new phenomena at once striking and unsuspected.

"As to the practical application, it appears to me decided by my experiments. It is no unusual thing to have Electro-Magnets which lift 2,000 lbs.; mine carried only from 30 to 40 lbs. at most; nevertheless these feeble magnets furnished me with a mechanical action equal to half the force of a man. To maintain this action during eight hours, scarcely half a pound of zinc is required, every thing being properly arranged.

"The superiority of this new motor, with regard to the absence of danger, the simplicity of the application, and the expense of the material necessary to keep it in action, is placed beyond doubt."

Extracts from a Lecture on Electro-Magnetism, delivered to the Philosophical Society at Zurich, (Switzerland,) February, 1833, *by the late* Dr. R. Schultess.

"Though Electro-Magnetism certainly is one of the most remarkable and interesting discoveries of modern times, yet it would create a much higher interest and gain in popularity, if it could be rendered practically useful.

"For some time past, I had been occupied with the idea whether the power of Electro-Magnets, which, without doubt might be infinitely increased, could be applied as a motive power for machinery."

After describing sundry experiments made by himself, he remarks;

"The result was now quite satisfactory. If we consider that Electro-Magnets have already been made, which were capable of carrying twenty hundred weight, and that there is no reason to doubt, that they may be made infinitely more powerful, I think I may assert boldly, that *Electro-Magnetism may certainly be employed for the purpose of moving machines.*"

Extracts from Notes on the Application of Electro-Magnetism as a Mechanical Power, by Professor Botto, *of the Royal University of Turin, (Italy,) published in* 1834.

"The remarkable energy with which the magnetic action is developed in soft iron, by induction from electricity in motion, is well known.

"The possibility of the application of this new power to machines possessing some interest, I have decided on publishing the results which I have obtained relating to this subject."

[Here follows an account of experiments.]

"I shall say nothing, at present, respecting some observations which I have on this occasion collected, upon the employment of different acid and saline solutions, and of sea water.

"It is not without especial interest that we contemplate these new effects of a force developed in so singular a manner from the masses of bodies; and it is difficult not to be carried away by flattering anticipations respecting the ulterior applications which the acquisition of this mysterious force suggests."

Extracts from a Treatise entitled Electro-Magnetic Experiments of SALVATORE DAL NEGRO, *Professor of Natural Philosophy in the Imperial University of Padua, (Italy,) published in* 1832.

"THIS new method, (by Sturgeon and Van Moll,) of communicating such great attractive power to iron, created in me the desire of repeating the experiments, and principally of taking into consideration the application of this attractive power, which it appears may be *infinitely increased*, to some useful purpose. I give these experiments to the public in the conviction that a force so easily evolved, and so *very powerful*, justifies repeated and varied experiments. In my experiments, new circumstances and new laws were observed and discovered, thus finally enriching natural philosophy with *a new motive power*"

Extracts from an Essay on Electro-Magnetism, by Professor SILLIMAN *of Yale College, published in his Journal of Science, April,* 1837.

After a sketch of the science, and a description of various machines, the Professor gives the following

CONCLUSIONS.

"1. It appears, then, from the facts stated, that Electro-Magnetism is quite adequate to the generation of rotary motion.

"2. That it is not necessary to employ permanent magnets in any part of the construction, and that Electro-Magnets are far preferable, not only for the moving, but for the stationary parts of the machine.

"3. That the power generated by Electro-Magnetism may be indefinitely prolonged, since, for exhausted acids, and corroded metals, fresh acids and batteries, kept always in readiness, may be substituted, even without stopping the movement.

"4. That the power may be increased beyond any limit hitherto attained, and probably beyond any which can be *with certainty* assigned,—since, by increasing all the members of the apparatus, due reference being had to the relative proportionate weight, size, and form of the fixed and movable parts,—to the length of the insulated wires and the manner of winding them,—and to the proper size and construction of the battery, as well as to the nature and strength of the acid or other exciting agent, and the manner of connecting the battery with the machine, it would appear certain, that the power must be increased in some ratio which experience must ascertain.

"5. As Electro-Magnetism has been experimentally proved to be sufficient to raise and sustain several thousands of pounds, no reason can be discovered why, when the acting surfaces are, by skilful mechanism, brought as near as possible, without contact, the continued exertion of the power should not generate a continued rotary movement, of a degree of energy inferior indeed to that exerted in actual contact, but still nearly approximating to it.

"6. As the power can be generated cheaply and certainly,—as it can be continued indefinitely,—as it has been very greatly increased by very simple means,—as we have no knowledge of its limit, and may therefore presume on an indefinite augmentation of its energy,—it is much to be desired, that the investigation should be prosecuted with zeal, *aided by correct scientific knowledge*, by *mechanical skill*, and by *ample funds*. It may therefore be reasonably hoped, that science and art, the handmaids of discovery, will both receive from this interesting research, a liberal reward."

APPLICATION OF ELECTRO-MAGNETISM TO NAVIGATION.

Since the foregoing pages went to press, we have seen the *London and Edinburgh Philosophical Magazine and Journal of Science* for September, 1839, in which we find the following highly important information, in a letter from Prof. Jacobi to Prof. Faraday. The former scientific gentleman has been for some time making experiments in the application of Electro-Magnetism to machinery, at St. Petersburg, being furnished with funds for that purpose by the Emperor of Russia.

Extract of a Letter from Professor Jacobi of Russia, to Professor Faraday of London.

"In the application of Electro-Magnetism to the movement of machines, the most important obstacle always has been the embarrassment and difficult manipulation of the battery. This obstacle exists no longer. During the past autumn, and at a season already too advanced, I made, as you may perhaps have learned by the gazettes, the first experiments in navigation on the river Neva, with a ten-oared shallop furnished with paddle-wheels, which were put into motion by an Electro-Magnetic machine. Although we journeyed during entire days, and usually with 10 or 12 persons on board, I was not well satisfied with this first trial, for there were so many faults of construction and want of insulation in the machines and battery, which could not be repaired on the spot, that I was terribly annoyed. All these repairs and important changes being accomplished, the experiments will shortly be recommenced. The experience of the past year, combined with the recent improvements of the battery, give us the result, that to produce the force of one horse (steam engine estimation,) it will require a battery of 20 square feet of platina, distributed in a convenient manner; but I hope that from 8 to 10 square feet will produce the effect. If heaven preserves my health, which is a little affected by continual labours, I hope that within a year, I shall have equipped an Electro-Magnetic vessel of from 40 to 50 horse power.

I take the liberty of sending you some memoirs from the *Bulletin Scientifique* of the Academy. The result of the joint memoir of myself and M. Lenz is, *that the attraction of Electro-Magnets is as the square of the force of the current, or as the square of the electrolytic action of the battery.* It appears that this most important law holds good for machines in motion; at least the experiments I have made on that point do not depart from it more than may be admitted as the error of observation, or the result of accidental circumstances.

I am, &c.

M. H. JACOBI.

St. Petersburgh, June 21, 1839.

ELECTRO-MAGNETIC ENGINE FOR RAIL-ROADS.

At the Twelfth Annual Fair of the American Institute, an exhibition of the power of Electro-Magnetism to propel railroad carriages is displayed, in a small locomotive Magnetic engine of less than 12 inches in diameter, which moves a car on a circular rail-road with sufficient force to carry a person weighing 150 pounds, seated in the car. This engine and apparatus have been constructed in this city at the establishment of the Electro-Magnetic Company.

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